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AUTHOR Heuston, Dustin H.
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ABSTRACT

The educational delivery system in the United States has matured, and investing more funds in the current system will have no effect in terms of effectively training students for tomorrow's society. Among the shortcomings of the current delivery system are limited individual instruction, inconsistent quality of presentation, limits of the teacher labor market, a diverse and rapidly changing student population, lack of information about individual student's needs, and faculty workload problem. However, once a condition exists in a mature delivery system that allows it to do exponentially more work for a reasonable financial investment, a dramatic system improvement is possible and such a condition is present in the advent of the computer. This paper includes discussions of technologies that will be available in new delivery systems, including videodiscs and compact disks, and warns educational leaders about some of the pitfalls of hardware acquisition. Topics discussed include the future of education; shortcomings of the current delivery system and advantages of the new delivery system; cost of implementation; possible productivity gains; technologies of the new delivery system; and the hardware revolution. (THC)

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THE FUTURE OF EDUCATION

A Time of Hope and New Delivery Systems

1986

Dr. Dustin H. Heuston
WICAT Systems
1875 South State Street
Orem, UT 84057 (801) 224-6400

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EXECUTIVE SUMMARY

This paper argues that society organizes around delivery systems in order to accomplish useful work. Once a delivery system matures there is no sense in spending more money on it because additional capital is wasted. The educational delivery system in the U.S. clearly has matured, and therefore investing more funds in the current delivery system will have no effect even though the delivery system has severe shortcomings in terms of training the students for tomorrow's society.

Once a condition exists in a mature delivery system that will suddenly allow it to do exponentially more work for a reasonable financial investment, then a dramatic delivery system improvement is possible even though most of the culture will not be prepared for the shift. Furthermore, the change will be inevitable, so state, national, and educational leadership should prepare to direct its resources in new educational delivery systems in order to help take advantage of the work bonus that the new technologies will generate.

The delivery system will not change slowly, but will shift in a binary fashion once all of the various components are working and in position. As we shall see, the advent of the computer will allow the educational delivery system to improve dramatically over the next decade. The condition now exists where for a very reasonable investment, exponentially more work will be available to help the students and teachers in their tasks.

By harnessing the speed of light in the form of running a million or more instructions per second, the computer can provide an extraordinary work bonus to the current educational delivery system. The usefulness of the work bonus will depend on how well the programming is done that will run the computer programs. The net result of well-programmed materials is that a high level of interactive artificial intelligence will be present at the student work station to interact with the student on an individual basis.

In a few years, through the use of special testing programs, the computer will understand how the learner learns on an individual basis and start to provide the instruction in a way that is tailored to the individual's learner profile. At this point the intelligence in the computer programs will outperform what the teacher can do in certain critical areas. Not that the computer is now as intelligent as the teacher, but in certain areas it will have enough intelligence so that its abilities to do a phenomenal amount of work will make it indispensable.

Then gradually as more sophisticated artificial intelligence techniques become available, the dialogue between the student and the computer will become more lifelike and helpful. Clearly, whatever the improved techniques are that are added, the computer will be able to improve the amount of individual instruction that each student can have in a school setting.

Oddly enough just as the computer will offer more individualization for the student, so will the teacher also be freed to give more individual attention

to each student since the computer is sharing the instructional load. Some scholars believe that the teacher will shift more to becoming a coach who will be helping the student achieve clearly defined mastery levels. Thus the teacher as a coach and motivator, rather than dispenser of information and judge, might be the future role of a teacher.

In helping in the added individualization the computer will also add an increased quality and consistency of presentation to the instructional process. Since the computer is "pupil blind" in terms of bias, it also avoids one of the greatest problems that underachieving children face, that of public humiliation. Thus at its best, a well-written computer program will offer outstanding instruction in a very consistent form that guarantees all the necessary steps have been presented, and the computer does this in privacy without risk of public humiliation. And for those students who need more trials than normal in order to master the materials, the computer offers infinite patience and support without any judgment.

The computer will also make a remarkable contribution to improving the instructional effectiveness and the quality of the current teacher labor force. It will do this in the following ways:

- The new computer delivery system will help improve the performance of the weaker teachers, particularly in the specialty areas such as mathematics, science, and languages. The computers will not only carry a significant portion of the instructional burden, but they will also help expose the teachers to an understanding of the disciplines that they themselves might not have yet fully mastered.

- The new delivery system will make a significant contribution by transitioning the student from primarily a passive role to one where he or she becomes an active learner through constant trials with feedback.
- Productivity gains will come from concentrating on learner productivity instead of just teacher productivity.
- Even in teacher productivity, however, the new delivery system will offer the only opportunity for true productivity gains in the educational delivery system. These gains will come from the traditional use of technology to free some workers up for other jobs, thus leaving the remaining workers in a better situation to improve their salaries.
- Finally, the advent of technology will generate a much needed sense of hope that will inspire teachers, principals, superintentendents, state superintendents, district boards of education, legislators, federal agencies and national leadership to work forcibly on behalf of education in a way that will attract many of the finest minds to educational careers.

The computer will also contribute solutions to one of America's greatest problems, that of student diversity. One of the best ways to help students who are in a difficult diverse social and intellectual setting is to help develop their language and educational skills through private interactions that do not publicly have them stand out. For example, as the computer curriculum matures, there will be excellent progrms with audio that can teach an Anglo child to read in a standard fashion, but the reading program will also have a parallel program that will teach the Hispanic students to read by utilizing an English as a second language program to help them learn to read

English as their second language. Thus a foreign-speaking child in Kindergarten could be working on an ESL reading program while the student next to him could be taking a standard reading instruction. Both programs will have excellent audio and instructional interactions with the student.

The new work bonus provided by the computers will provide not only the capacity to individualize instruction, but also a new capability, through a field called "computer-adaptive testing," to clarify all sorts of useable information about the student's current knowledge, learning style, latent abilities, etc. Generally speaking, computer-adaptive testing has three distinct advantages:

(1) It is much more accurate than standard testing.

(2) It can administer the test in far less time.

(3) The results are available immediately.

The computer-adaptive testing program will also generate a new field called computer-adaptive learning. Once the students have had a "learner profile" developed by these tests, the programs will automatically offer instruction in a way that the students can best learn. Here we have an example of a really fundamental revolution in instruction because the educational delivery system will use the work bonus in testing to learn more about the students and invidualize their instruction than could ever be done by the standard system, no matter how diligent the effort of the teachers. Other new areas will spring up as individual learning decay rates are calculated so the computer programs will know when it is optimal to refresh a student so he does not forget what he has just learned.

The computer will also help the teachers insure that the instruction they give is mastered by the students. The work bonus will complete the instructional loop that frequently ends before the mastery is achieved. The computer will also pick up many of the paper work chores that a faculty member is currently burdened with.

This paper suggests that the cost of implementing computer instruction will vary among districts but should cost approximately $50-$100 per student per year. The additional cost should be between 2-4 percent of the district's budget. The paper also points out that if districts are willing to add additional students to sections, the district would be able to generate some significant productivity gains that will pay for the computer implementation and generate significant revenue for higher faculty salaries. The addition of a few children per section will not damage the instruction because the computer will more than offset any loss of individualization as a result of larger sections.

Using these budgetary figures, students should be on computers for approximately half an hour a day. As districts learn to become more efficient in their use, and the price of the hardware continues to decline, for the same investment districts will be able to have students spend approximately an hour a day, or 1/6 of their time on computer terminals.

The paper concludes with a discussion of the various technologies that will be available in the new delivery systems and tries to alert educational leaders to understand some of the pitfalls of hardware acquisition.

THE FUTURE OF EDUCATION
A Time of Hope and New Delivery Systems

Many of the greatest changes in society have come when a delivery system shifts because of the introduction of a new technology which allows it to accomplish more work. The changes rarely occur without detractors and severe criticism and skepticism. This skepticism is certainly well-founded if one were to analyze all of the breathless predictions of future change that are constantly offered by society's prophets. Nevertheless, there are some general indicators that can be tested to see whether a delivery system is likely to change dramatically in accord with prophetic commentary.

The important indicator that suggests that a delivery system will probably change is that the addition of some new technology will allow exponentially more work to be done in that delivery system assuming the cost increase is reasonable. We tend to use technology depending on not just how much more work it can do, but whether or not it is cost justifiable. For example in traveling we sometimes walk, use a bike, drive cars, or even fly. Theoretically it might be possible to use a rocket to get from one point to another even more rapidly, but there are only a few uses that could support the extraordinary financial investment required to use the potential of a transportation system driven by a rocket.

The important point is that once a delivery system has new technology which is reasonably priced and that can do exponentially more work for the users, then

a condition exists that produces an inevitable change in the delivery system. Tanks will defeat calvary, automatic weapons will outperform bows and arrows, cars will outperform horses, and television will enter most homes. As delivery systems begin to change because the new condition is met, there are a number of interesting phenomena that take place:

(1) The purveyors of the current delivery system are rarely those who take a leadership position using the new delivery systems. The horse-drawn carriage manufacturers did not invent the automobile, nor did the automotive industry support the airplane industry.

(2) In those industries that have a monopoly, such as is in the case of the military, the changes frequently come with an extraordinary internal tension as the users of the old delivery system fight with the sponsors of the new. When Billy Mitchell proved that aircraft could sink Navy ships he was court-martialed.

(3) Skeptics confuse the issue, usually appealing to human values as opposed to cold, ruthless, and calculating technology. The horseless carriage was often attacked as being unreliable, inhuman, smelly, and something totally devoid of feelings.

(4) The delivery system cannot change until all of the new technology factors work quite efficiently. Changing a delivery system is a binary process; until all the factors work, the new delivery system itself will not be

very effective. Cars needed roads, manufacturing plants, gasoline and repair facilities in order to be accepted. Aircraft needed airports, a fuel industry, advanced aeronautical theory, etc. Trying to get a delivery system to function without all the parts being ready is as difficult as becoming just a little bit pregnant. The delivery system either has all the components in position and can work, or it cannot.

(5) Prior to the moment when all the pieces work, thus allowing the delivery system to change, critics have a field day over the repeated failure of the various efforts. In the early 1900's a car would race a horse at a race track. Part way through the race the car would break down, and the horse would then tow the car across the finish line proving once again that cars would never replace horses.

(6) No matter how much bias is generated by the critics or how confused the situation becomes to the public, or how much the current delivery system drags its feet, the outcome is inevitable. The reason people appear to miss the inevitability of the outcome is that they fail to understand the mathematical inevitability of the process. A simple equation can help explain this.

The Delivery System Equation

1		2		3		4
number of workers available	X	efficiency of workers through research and training	X	work bonus factor	=	total useful work

The boxes suggest the components of a typical delivery system which generate some amount of useful work.

Since most delivery systems do not change very frequently, the users of the delivery system tend to forget Box #3 and concentrate all of their efforts on Boxes 1 and 2. Thus foundations and government agencies pour millions of dollars into research in education believing that somehow this will lead to a better way of doing things. In truth the real leverage comes from Box 3. When a delivery system is able to introduce some work bonus factor, such as technology, which will do exponentially more work, then the delivery system potential increases dramatically. Unfortunately, we tend to think, even after the shift, in terms of Box 1 and 2. Ninety-nine percent of the foundation directors and trustees and government leaders currently believe in Box 2 when discussing education. Thus almost all the grants have to do with somehow enhancing Box 2, even though the advent of the computer will allow education to do exponentially more work at an affordable level in Box 3.

A simple analogy might help clarify the issue. The horse is a useful example because by definition it can do one horsepower worth of work as a work bonus factor. Thus a delivery system that uses a well-trained human to work with a horse can expect to get one useful horsepower out of the horse.

Using a facetious example, suppose that the horse were our only means of transportation, and yet all our current government agencies agreed that

the transportation system using the horse needed more investment. Congress would allocate tens of billions of dollars to meet this new national crisis. The Department of Education would receive a $10 billion allocation to figure out how better to train the horses and the riders to do a better job. The National Institute of Health would receive $10 billion to work on dietary considerations for both the horse and the rider. The National Institute of Health would receive $10 billion to improve the technology of the horseshoe. They would come up with the invention of the titanium horseshoe to increase efficiency. Another $10 billion would go to NASA to aerodynamically improve the horse. After doing a great many simulations they would work out the ideal way to comb the horse's mane and tail to reduce friction. Thus after a $40 billion investment the horse might average 1.1 horsepower instead of 1 horsepower. Conversely had the money been used to invent the car, the horsepower would go from 1 horsepower to 400 horsepower, or the jet aircraft, at say 40,000 horsepower. Notice how the real improvements in a delivery system come from some work bonus factor being introduced, usually some technology breakthrough which allows exponentially more work to be done by the workers in the system for a reasonable additional cost.

One of the more interesting examples of a change being forced on a delivery system by a new technology occurred in the 1860's when the telegraph was hooked up from coast to coast as competition to the Pony Express. As a matter of commercial fact, the Pony Express lasted about five days after the telegraph was hooked up. The reason for this is that the message could be sent from coast to coast on a telegraph, while in

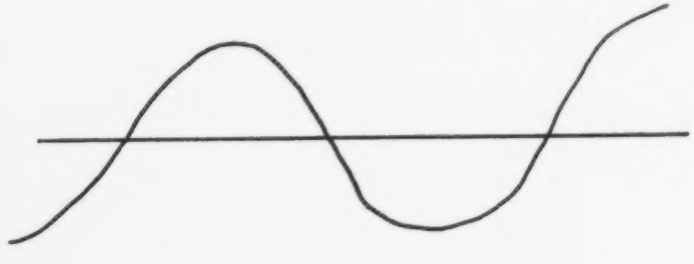
the old delivery system, the rider was still trying to mount his horse to start west. The dramatic difference here is the telegraph harnessed the speed of light, or the electron, and hence the pony's efforts never stood a chance.

But the fictitious example of the government putting more money into improving the horse by investing heavily on Box 2 instead of Box 3 has a very significant lesson. Leaders who feel pressure from their constituents to improve their services tend to think of increasing their budgets for the current delivery systems in hopes that they can aid them. But here it is important to note that once the delivery system has achieved maturity and people have become well-trained in using it, putting more money in to the mature delivery system produces no additional benefit. In fact, it seems to have a negative impact in that it depresses the population to see that the additional investment has no discernible impact.

The educational delivery system is a perfect example of this phenomenon. In slightly over 100 years, we have gone from educating 400,000 students in elementary and secondary schools to over 40,000,000 per year. Education has been the great hope of democracy in giving equality and opportunity to the young in America. Unfortunately, the educational delivery system has matured, and no reasonable amount of financial investment will improve it to the extent required to serve the needs of the culture. Between 1950 and 1975 the percentage of the gross national

product spent on education went from 3.4 to 7.4 percent, an increase of 118 percent. Unfortunately, this more than doubling of the investment did not translate to any improvement in educational scores. In fact, they fell slightly. More recently the per pupil cost in the U.S. rose from the 1970-71 school year of $911 per student to $2,724 per student in school year 1981-82. After inflation is factored in, there was an increase of 34 percent in real dollars during this period, and again scores did not improve.

Leaders tend to get confused because they are always being urged to follow some new innovation relating to a box 2 improvement. Thus there is an ineffable belief that if some of the exciting improvements that can be located in various educational institutions as a result of research projects can be transmitted to other institutions, then a great improvement will take place in the delivery system as a whole. In fact, this never happens because for every improvement in one area of a mature delivery system, there is a falling off of efficiency in some other area. Studying the history of a typical school district shows how individual schools rise and fall in terms of performance over time. It seems impossible to get all of the units improved at once. In fact, the problem can best be approximated by the picture of a sine wave.



Since every delivery system has both very good and very poor practitioners, there will always be portions of it that perform well and sections of it that perform poorly. The sine wave phenomenon is important to understand because it clarifies the futility of trusting in some new approach used by some group that appears to be beating the system through an unusual approach.

Frequently as people are frustrated by the inability of a delivery system to improve, they launch vigorous efforts to change it without realizing that the same strategies have often been tried as many as half a dozen times in the past few decades. Well-intentioned critics will offer solutions which tend to fit their own knowledge base. For example, businessmen frequently look darkly at the teachers and mutter about the need for improved productivity without considering that for 500 years we have been trying to improve teacher productivity without having an appreciable impact. Similarly, they often think that by giving financial advice to the districts they can get the system financially accountable, and hence the schools will improve.

Enthusiasts from other professions will frequently try to attack the work market by coming up with suggestions that will improve Box 1. They sometimes introduce paraprofessionals, parent volunteers, team teaching, or even peer teaching. What these sponsors sense is that the system needs more useful work, and they are trying to provide auxiliary

personnel to add work. Unfortunately, these approaches have failed for 50 years, so there is no real need to try them one more time. One of the problems education has is that since most people have gone to school, they are experts in giving advice on how to improve the system even though the growth trends that are dictating the realities of the system may be entirely invisible to them.

Summary:

The most important aspects of delivery systems are:

(1) Once a delivery system matures there is no sense in spending more money on it because additional capital is wasted. The educational delivery system in the U.S. clearly has matured, and therefore there is no sense pouring more money into it to improve it even though the delivery system has some shortcomings in terms of training the students for tomorrow's society.

(2) Once a condition exists in a mature delivery system that will suddenly allow it to do exponentially more work for a reasonable financial investment, then a dramatic delivery system improvement is possible even though most of the culture will not be prepared for the shift. Furthermore, the change will be inevitable so it is to the leadership's advantage to direct its resources to help take advantage of the new opportunities.

(3) The delivery system will not change slowly, but will shift in a binary fashion once all of the various components are working and in position. As we shall see, the advent of the computer will allow the educational

delivery system to improve dramatically over the next decade. The condition now exists where for a very reasonable investment, exponentially more work will be available to help the students and teachers in their tasks.

The Shortcomings of the Current Delivery System and the Improvements of the New Delivery System

Although from a theoretical standpoint, the problems of the current educational delivery system are a function of the delivery system having matured at a fixed work level, the shortcomings themselves are not theoretical at all, and the results of the work limits can be clarified very quickly. Some of these limits are:

(1) Limited Individual Instruction.

Although the dominant image in American education has a loving teacher with an arm about a student's shoulder where individual attention and instruction is being given, the reality of the current educational delivery system is that the teacher can only give a little individual instruction to each student because of the work limit imposed by the delivery system. Researchers have studied in classrooms with stopwatches and tracked what actually happens during a school day, and they have found that generally speaking students can only have 10 seconds of individual instruction for every hour spent in class. This means that in a 6-hour school day, the average student in an elementary school in the U.S. has approximately one minute of individual instruction. In a

180-day school year, this means that each student has approximately 1/2 a day of individual instruction per year, and when this statistic is extrapolated to the entire elementary and secondary school, this student will graduate from school with slightly less than one full week of individual instruction for the previous 13 years of school attendance. The mathematical reality is that 1/360th of the time spent in school is apt to be in individual instruction. The best teachers who concentrate very hard can sometimes double this statistic, but even two weeks of individual instruction over 13 years is not enough for many students.

An additional element that is not particularly encouraging is that even when a paraprofessional is added to the classroom structure to help the teacher, there is not a significant difference in the amount of individual instruction given. This suggests that the attempts to meet the work limit by adding in volunteer and paraprofessional labor is not going to make a very significant difference. One book that discusses this issue is Eaton H. Conant's volume, Teacher and Paraprofessional Work Productivity, published by Lexington Books of D.C. Heath in 1973.

The Computer's Contribution to the Individualization Problem

By harnessing the speed of light in the form of running a million or more instructions per second, the computer can provide an extraordinary work bonus to the current educational delivery system. The usefulness of the work bonus will depend on how well the programming is done that will run

the computer programs. The net result of well-programmed materials is that a high level of interactive artificial intelligence will be present in the terminal to interact with the student on an individual basis.

Even the most simple drill and practice programs have a fairly high level of intelligence that can be a great help to a school. For example if a student just types his name in to begin a math drill and practice program, in an act of intelligence the computer recognizes the student's name and automatically gives him a problem appropriate to his current proficiency level. When the student answers, in another act of intelligence, the computer decides whether the answer is correct or not and informs the student. Then using further intelligence the computer records what the student has just done so there is a record for the teacher. Some of the more sophisticated programs move on to additional individualization. For example, the computer might decide that the student is missing too many problems, and therefore the level of difficulty is too high. The computer, again using an act of intelligence, can lower the level of difficulty until it fits the individual student's needs. Furthermore, in some of the more advanced programs, the computer's intelligence can offer a private tutorial to the student if the student continues to miss the problem. For example, having seen the student miss the problem twice in a row, the computer might automatically clear the screen and present the problem that has just been missed on the screen, and then using graphics and animation, help the student work through the problem with a series of prompts and

animations until the student has solved the problem with the help of the computer.

In a few years, through the use of special testing programs, the computer will understand how the learner learns on an individual basis and start to provide the instruction in a way that is tailored to the individual's learner profile. At this point the intelligence in the computer programs will outperform what the teacher can do in certain critical areas. Not that the computer is now as intelligent as the teacher, but in certain areas it will have enough intelligence so that its abilities to do a phenomenal amount of work will make it indispensable.

Then gradually as more sophisticated artificial intelligence techniques become available, the dialogue between the student and the computer will become more lifelike and helpful. Clearly, whatever the improved techniques are that are added, the computer will be able to improve the amount of individual instruction that each student can have in a school setting.

(2) <u>The Class Ability Spread Problem</u>.

Not only does the teacher have the distinct problem of being able to offer enough individual instruction, but also he faces a severe problem during general teaching sessions when addressing a class because much of the instruction he gives is inappropriate to the needs of his students. The underlying problem in the class is that the student ability begins to

spread more and more as the students get older. A good rule of thumb is that the student ability spread in a given class is as many years as the grade level of the class. Thus in the second grade there are probably two years of ability in a given section; whereas, by the 8th grade there are probably 8 years of ability difference in a given section. That is to say that some student in the class will be reading at the 4th grade level while another will be reading at the 12th grade level. The problem the teacher faces is that he is forced into teaching to some indeterminate middle in hopes of covering as many students as possible. The best this can be called is teaching through compromise or approximation.

The Computer Contribution to the Spread Problem

Obviously to the degree the computer individualizes, it helps relieve the teacher of teaching through approximation. At the same time the computer will also help solve the spread problem because it will start to relieve the teacher from being the only source of instruction. It will take a number of years to define the future teacher's role when the technology and necessary software are mature, but clearly the teacher will no longer have the onus of being the only provider of the information in an interactive setting. Oddly enough just as the computer will offer more individualization for the student, so will the teacher also be freed to give more individual attention to each student since the computer is sharing the instructional load. Some scholars believe that

the teacher will shift more to becoming a coach who will be helping the student achieve clearly defined mastery levels. Thus the teacher as a coach and motivator, rather than dispenser of information and judge, might be the future role of a teacher.

(3) The Quality and Consistency of Presentation Problem

The possibility that a student will receive a thorough and clear presentation from a teacher is probably a lot less than most people realize. There are a number of reasons that a teacher might not offer a first-rate presentation. Some of these are:

- Questions from the students can frequently throw a teacher's presentation off so that not all the instructional steps are explained clearly.
- The teacher may be inexperienced and not yet performing well.
- The teacher's knowledge might not be up to the level required. For example as there are increasing shortages in math, science, and language teachers, unqualified teachers are asked to substitute in these areas.
- The teacher may be tired or ill on a given day.
- The teacher may be 'burned out.' We forget that after teachers have taught successfully for 10 years, they could still be teaching for another 30-35 years after that. Many become burned out because they are improperly handled by their administrations.
- Some teachers are simply incompetent.
- Discipline distractions interrupt instructional presentations far too frequently. In some schools, the teachers feel they are successful

if they can just keep a class from going out of control because of serious disciplinary problems.

- The teacher might be disorganized. This can be particularly difficult for the students because a disorganized teacher will either leave out important steps that are needed for mastery of the material, or over-emphasize less significant points, which will be confusing for the student.
- The problem of teacher bias toward students. Frequently teachers like certain kinds of students and dislike others. They tend to like neat, attractive and orderly children and be put off by those who are noisy, restless, unattractive, and apparently not too bright. Sometimes the least attractive and least talented students will be exposed to teacher bias, and instead of receiving patient and consistent instruction, they will more or less be ignored. Thus the students who need extra attention and great patience from their teachers will, in some cases, be the least likely to receive it.

Computer Contribution to the Quality and Consistency of Presentation Problem

A well-written instructional computer program gets rid of most of the instructional problems of consistency and quality for two reasons:

(1) The process required to build effective computer courseware almost assures that the materials will be prepared in an orderly and

instructionally sound manner. Generally, the materials are developed by hiring a team leader who has a Ph.D. in the particular discipline being prepared who then also works with a panel of national experts in the discipline as well as some developers who are former teachers. The team leader and the panel work out the general instructional approach. Then the team starts a process where each instructional step is analyzed very carefully and written first in a paper sequence. Then the sequence is programmed and evaluated for instructional effectiveness. The consultants who have helped design the overall approach review the paper version first. Obviously a presentation that has been worked on by many experts over many hours, each step of which has been carefully defined and evaluated, is apt to be more consistent and effective than the average presentation by a faculty member who is thinking on his feet while presenting the materials having just reviewed the materials for a few moments.

(2) The computer has the potential to present the materials in a sequence that has been carefully worked out in an organized fashion. Thus the concern about having a teacher deliver a consistent and well-organized lesson is taken care of by having the computer deliver some of the instruction.

But the computer also has another advantage for the students because by its very nature it has infinite patience and will reteach the same points

over and over again until mastery is achieved. In this way the computer may be said to be "pupil blind" in terms of bias. It also avoids one of the greatest problems that the under-achieving children face, that of public humiliation. No one likes to be embarrassed. The pain of public humiliation cannot be overestimated, and one of the most attractive features of the computer interaction to the students is that their learning trials and feedback are done in a private fashion. No one need know whether they have answered the question right or wrong, and the machines will offer helps with endless patience without any sense of judgment. Thus at its best, a well-written computer program will offer outstanding instruction in a very consistent form that guarantees all the necessary steps have been presented, and the computer does this in privacy without risk of public humiliation. And for those students who need more trials than normal in order to master the materials, the computer offers infinite patience and support without any judgment.

(4) The Teacher Labor Market Problem

The current educational delivery system in the U.S. at this time faces some problems which, while they may not be insurmountable, are certainly more critical than most people are aware of. These issues have to do with the type of teachers who will be available to be hired and the amount of money which will be available for education. Generally speaking the teacher population is drawn from among the least intelligent college graduates. There are many obvious reasons for teaching not

being an attractive profession financially, and many articles have explained what the low salary base is doing to the quality of the incoming teachers. Unfortunately there are probably some profound economic processes at work that most educational commentators are unaware of that will constrain any efforts to solve the salary problems by simply pouring more money into education. These economic constraints are related primarily to national and educational productivity issues.

The United States will not be able simply to raise salaries endlessly in an attempt to improve the teacher salary structure and attract a more qualified faculty member. The late Patrick Haggerty of Texas Instruments wrote some very perceptive papers on the problem of educational productivity. In his work he pointed out that, ignoring inflation, any activity that expected financial increases on a regular basis could only have the national economy afford it if that activity achieved some kind of improvements in productivity. His analysis of education suggested that this was an area where people were ignoring the productivity issue and hence sooner or later would run into financial limits that people were not yet aware of.

Drawing on Bowen's work at Princeton University, Haggerty noted that if a large scale economic activity continues to raise wages without producing productivity gains, then inevitably that activity will have to raise its prices each year and would take a greater percentage of the gross

national product. As we mentioned earlier, between 1950 and 1975 the percentage of the gross national product spent on education rose from 3.4 to 7.4 percent. Expenses in constant dollars on a per pupil basis rose almost 3 times between 1950 and 1970. More recently cost per student rose from $911 in the 1970-71 school year to $2724 per pupil in the 1981-1982 school year. At some point, however, the nation cannot afford real increases in salaries without commensurate gains in productivity.

Haggerty points out the extraordinary contrast between educational and agricultural productivity. In agriculture the number of workers required to produce food for the nation decreased from 9.4 million in 1890 to 3.3 million in 1972. The workers saved by these productivity gains have been freed to work in other businesses. Without the availability of these workers many businesses would not have been able to grow. Also, imagine the cost of food now if the percentage of the work force required for agriculture had not declined from 40 percent in 1890 to less than 4 percent in 1985. Had this decline not taken place, over 40 million more workers would now be required for growing the nation's food. Without similar productivity gains being available in education, then inevitably after costs have risen to some percentage that begins to impact too many other programs, the wages of teachers will stagnate and the culture will continue not to be able to afford to attract the brightest teachers.

Part of the salary resistance will come as a natural result of reaching financial limits in what the country can afford in terms of the gross

national product. Haggerty points out that in the 40 year span between 1930 and 1970 that while the number of students in the population doubled, the number of workers in education were up 4 times, and during this period, the expenses in constant dollars on a per pupil basis nearly tripled. Thus not only has education not become more productive, but instead has become far less productive as 4 times the number of workers have been hired to take care of 2 times the number of students.

But even while these limits are causing salary restrictions that will inhibit the ability of the educational establishment to attract top rate teachers, there are some additional contemporary trends that are further exacerbating the problem. Some of these trends are:

- The bright women who have been the backbone of the teaching profession are beginning to leave the profession in great numbers for jobs that will pay anywhere from 2-5 times as much salary, or they are not even considering going into teaching because other better paying career options are available to them.

- As society's needs for specialists in physics, electronics, programming, mathematics, and languages, has increased, industry has begun to pay trained personnel in these areas very high wages. This means that many qualified teachers, both male and female, who are competent in these specialties are being hired away by industry. This depletion of the brightest specialists is causing a quiet crisis of

its own because many of the most difficult academic areas are now no longer being staffed with competent teacher. For example, there are approximately 15,000 public school districts containing 85,000 schools. In these 15,000 districts, at last count there were something like only 10,000 physics teachers, or less than one per district, not to mention the number of high schools without them. This trend will probably not improve because of the high technology boom in this country.

- The population statistics for the next decade will further exacerbate the problem because more students are beginning to move up through the school system. The already thin veneer of talented teachers and trained specialists will soon be stretched even finer as we begin a new cycle of teacher shortages.

- The percentage of taxpayers with children is falling to too low a percentage to support extensive bond issues in most areas. Probably on a national average the percentage of the voting population with children in the school system is now slightly less than 20 percent. This means that the voters with children who care about raising the local taxes are being outvoted by families who have no vested interest in increasing their taxes for the local public schools.

In addition to the inevitable salary barriers caused by the productivity problem, there is another fundamental issue facing future educational funding. This problem is also a subtle one which is not recognized by most commentators. Since the educational delivery system is mature, additional funds are not improving the quality of education. This failure to improve education, despite a massive build up in spending, has damaged both public and educational leadership support for funding, and even more significantly, it has had a devastating effect on educational morale.

In the early 1970's the superintendent of the Dallas School District, Dr. Nolan Estes, noted that the district expenditures had gone up 3 times during the past 10 years, and despite significant financial efforts and sacrifice, the performance of their poorer children in the Title I schools did not improve between 1965 and 1970. In fact, after the district did all it could financially, he found in 1970 that some of the schools were performing less effectively than they had 5 years earlier.

Summarizing the impact the experience had on him, and the public, he wrote: "Ten years ago, we educators confidently asserted that we knew how to cure educational illness. All we needed was enough money to lower pupil-teacher ratios, put a library in every school...and so on and so forth. Our prescriptions for educational excellence were based on traditional notions that went unchallenged because a stingy public had never allowed us to try them.

During the 1960's we got a chance to try them...and the results did not justify the investment. And today, it is clear, the public does not believe it is getting its money's worth from public education."

This poignant lament speaks not only to the problem of future funding, but to the even more significant trauma of not believing that education can really be improved, even though there are millions of children who desperately need better educational help. In some ways the loss of hope is the worst of all.

In summary the quality of educational personnel will not be as strong as would be ideal, and there are a number of forces working against any simple solutions. Generally speaking, the trends seem to suggest:

- The cost of education will continue to rise because of normal salary raises in the school system.
- The cost will not be offset by productivity gains unless a new approach is used in the educational delivery system.
- In fact, in an effort to improve education, more and more teachers have been hired which has caused an overall decline in educational productivity.

- At some point, society cannot afford to continue to pay an ever increasing percentage of its gross national product to education, so salaries will begin to stagnate.
- As salaries stagnate, the better teachers will continue to leave the system, or will not even join it.
- As the now mature educational delivery system grows weaker because of its decreasing quality of personnel, the public will give it less and less support because it believes that the additional expenditures are not improving the educational system.
- Finally, despite constant cries for reform, both the public and the leaders feel a deep pessimism and a great lack of hope about the potential for real improvement of the educational system.

The public will not be sophisticated enough to articulate that it is facing a mature delivery system that cannot be improved no matter how much money is spent in a traditional manner. Nor can the public conceptualize that as a result of its inability to improve productivity that salaries must inevitably stagnate, and hence schools will be staffed with less talented personnel at a time when the nation needs to train its population in knowledge-based careers in order to compete internationally. But although the public may not be able to articulate the reasons for the problems, the public is perceptive enough to know that something is wrong in the educational delivery system. The recent national educational reports have indicated the public senses the nation

is "at risk" in its current educational policies, but at the same time the public is also increasingly certain that putting more money into the system will not improve it unless there are some fundamental changes.

The Computer Contribution to the Teacher Labor Market Problem

The way the educational computer will contribute to the teacher labor market problem is to embed a guaranteed level of excellence of teaching in all specialty disciplines that will enable the students to be taught by teachers who might not be as well trained as would be ideal. Thus districts who might have an enthusiastic but not very well trained physics teacher will now have the opportunity to receive strong support from the computer curriculum. Not only will the interactive lessons on the computers teach physics very well to the students, but also the teacher will be able to master the discipline himself by taking the lessons and becoming familiar with the materials on the computer.

The productivity issue is a very interesting one because there has been a great deal of misunderstanding about how we can improve productivity in schools. Conventional wisdom has fastened on the teacher as being the instrument of cost and hence the area in which to seek productivity improvements. Attempting to use the earlier technologies to further this end, educators have tried to replicate the teacher on videotapes, radio, tape cassettes, television, and tape recorders. The assumption has been that by replicating the teacher's presentation the teacher could be made far more productive.

The weakness of this approach is that it does not allow student individualization, and it keeps the student in a passive role. Without individual attempts at mastery with adequate feedback, the student simply sits passively in front of the presentation without really becoming integrated into the learning process. What has not been understood by either society in general, or the educational establishment in particular, is that the computer differs from all other technologies because it alone contains artificial intelligence which allows it to individualize instruction and interact with a student by forcing trials with feedback. Much confusion has been generated by lumping all technologies, including computers, into one amorphous mass. All the other current technologies have a limited usefulness because they keep the learner passive and cannot individualize.

An important corollary, however, in terms of discussing the educational process in terms of productivity is that the computer allows us to shift the focus on productivity from the teacher to the student. Quite logically if there are 25 students and one teacher, if a process can dramatically improve the productivity of the 25 instead of the one, then the delivery system is making an extraordinary contribution to productivity. In the years ahead, attention will be focused on <u>learner productivity</u> rather than teacher productivity. An active learner being given almost unlimited trials with feedback is far more productive than a student being given an "approximate lecture" where he sits passively. A further interesting economic consequence is that we will begin to discuss the learner as a cost element as well as the teacher. An unconscious

assumption is going to be re-examined which held that since the teacher had a salary and the learner did not, the real cost was in the teacher. While no actual salaries may be paid to the students, the entire educational tax and tuition base is on their behalf so they are costing society a great deal.

Furthermore, and even more importantly, to the extent that they are not trained effectively, they can cause a future economic drain on the society for 50 years or more. For example, when 42 percent of the 17-year old Blacks in America are functionally illiterate, then many of them will be unable to work, and they will cause real productivity problems to America. The cost of American goods will have to include not only the cost of the workers, but also the cost of the people the workers are supporting who are out of work with unemployment, welfare, or retraining benefits. Or even more sadly, there is a significant hidden productivity cost when some of the unemployed end up in prison because of the significant cost of maintaining a prisoner. There is no necessary corollation between illiteracy, poverty, and crime, but many observers feel that if children are trained well enough to be able to work in reasonable careers, that there would be less crime. Obviously if technology can guarantee to make a youngster literate, then some of the unemployment and prison productivity drain need not occur. As this issue is understood more clearly, we will inevitably move to a heavy use of technology to assure that students become competent in their basic disciplines and that learner productivity is improved to the point where the students can join a knowledge-based work force.

As the courseware and technology matures, computers will make a contribution to the productivity problem by allowing a teacher to teach more students and an administrator to oversee more schools. Since the computers will help the teachers with many of their paperwork chores and the students by increasing individual instruction, the teachers will support their usage and some reasonable increase in class size. The administrators will do the same when they realize that the computers will be able to help them with their administrative tasks such as payroll, accounting, budgeting, forecasting, bidding, scheduling, testing, attendance, and grading. The information will also help the districts to offer accurate reports to their constituencies such as parents or legislators.

In short, the computer will add a dramatic increase in productivity to the educational delivery system which can increase its quality while moderating its, cost, much as technology has improved productivity in other areas of the economy such as agriculture.

An important by-product that may actually turn out to be more significant than any of the other advantages is that the advent of the new delivery system will generate a new sense of hope in educational planning and policy making. As the superintendent from Dallas noted, for decades the educational leadership felt that if they just had more funding, they would be able to improve the system a great deal. The spending binge in

the 1960's and 1970's did not improve the system at all, so the profession is dispirited and has had its underpinnings in strategies for any potential improvement severely damaged.

The potential of technology will generate a new generation of hope which will invigorate the educational profession, the taxpayers that support it, and the legislators who control its funds. Organizations rarely stay static, and education has been in a constant decline since the leadership recognizes that the best that money could buy was not improving anything. Conversely a sense of hope will help the system improve because it will generate excitement among professional leadership, the teachers themselves, the critics of the system, and all of those who interact with education.

This new excitement and commitment will begin to attract the best minds because they will see that their efforts and influence will make an unusual difference as the new delivery system exponentiates the amount of work available to help students learn. This excitement and commitment of the best minds will lead in turn to increased funding. The funding will be paid for by the productivity gains, but it will also allow the faculty salaries and leadership salaries to be high enough to upgrade the tone and professionalism of the educational sector. In the end, this new sense of hope will help generate an absolute improvement in the effectiveness of schools as benign neglect is put behind and a new type of professional commitment is generated.

Summary:

The computer contribution to the teacher labor market problem will be derived from a number of improvements:

- The new computer delivery system will help improve the performance of the weaker teachers, particularly in the specialty areas such as mathematics, science, and languages. The computers will not only carry a significant portion of the instructional burden, but they will also help expose the teachers to an understanding of the disciplines that they themselves might not have yet fully mastered.
- The new delivery system will make a significant contribution by transitioning the student from primarily a passive role to one where he or she becomes an active learner through constant trials with feedback.
- Productivity gains will come from concentrating on learner productivity instead of just teacher productivity.
- Even in teacher productivity, however, the new delivery system will offer the only opportunity for true productivity gains in the educational delivery system. These gains will come from the traditional use of technology to free some workers up for other jobs, thus leaving the remaining workers in a better situation to improve their salaries.
- Finally, the advent of technology will generate a much needed sense of hope that will inspire teachers, principals, superintendents, state superintendents, district boards of education, legislators, federal agencies and national leadership to work forcibly on behalf of education in a way that will attract many of the finest minds to educational careers.

(5) Student Diversity Problem

One of the problems that plagues the American educational delivery system is the diverse and rapidly-changing nature of the student population in many areas of the country. America has always prided itself on being a melting pot where immigrants from many unique backgrounds have been assimilated by the culture. The public schools have had an important role in helping the assimilation. For many decades there were plenty of jobs available for people with minimal literacy skills, so if the public school was inefficient in its instruction because of the immigrant problem, this did not have a strong impact on the working potential of the graduates. More recently, however, with the jobs increasingly coming from the knowledge based sector, the diversity problem, with its negative impact on the performance of the students, has led to severe hiring problems for some of the graduates, not to mention the dropouts, of the public schools. When different cultural traditions mix in the school, this generates student differences, faculty-student differences, and parent and board differences, and hence the effectiveness of the school decreases. Any loss of efficiency inevitably damages the product of the school.

It would be difficult to overestimate the important advantage that a country like Japan has with its predominantly homogeneous population. For over a thousand years Japan had almost no immigrants, and as a result the society is extremely stable in its educational settings. Because of

the homogeneous population and cultural traditions, a teacher in Japan can control a class of 45 students with less discord than a typical American school with 15 students. The nation as a whole believes in education, so they have on average over a third more school days per year than America. Thus not only is the classroom run substantially without discipline problems with a very clear and properly-understood charter, but also many more hours are spent in formal school settings. The combination of efficiency and additional time is preparing an unusually well-trained population that is ready for the jobs of a knowledge-based society. Contrast this to a large melting pot city such as New York now that has an overall dropout rate in excess of 40 percent, with some of the boroughs reaching as much as 80 percent. The economic, social, and personal consequences of these drop out statistics are devastating.

The Computer Contribution to the Problem of Student Diversity

One of the best ways to help students who are in a difficult diverse social and intellectual setting is to help develop their language and educational skills through private interactions that do not publicly humiliate or have them stand out. For example, as the computer curriculum matures, there will be excellent programs with audio that can teach an Anglo child to read in a standard fashion, but the reading program will also have a parallel program that will teach the Hispanic students to read by utilizing an English as a second language program to help them learn to read English as their second language. Thus a

foreign-speaking child in Kindergarten could be working on an ESL reading program while the student next to him could be taking a standard reading instruction. Both programs will have excellent audio and instructional interactions with the student.

Where the computer is particularly effective is in adding efficiency to the instructional process. Since each student is working individually while interacting intelligently with the programs, the student is free from the distraction that frequently plagues a group interaction. This efficiency will not easily allow students to fail to master the basic curriculum. As the new delivery systems mature, the students will probably spend approximately 1/6 of their day on computers, and these interactions will have the students moving forward at a steady pace in their educational progression. Thus the new delivery systems should make a strong contribution in helping to alleviate the diverse student population problem. This in turn will assure that the student graduates will be prepared to find work in a knowledge-based work force.

(6) The Student Information Problem

A problem with the current educational delivery system is the difficulty a teacher has in trying to gain enough information about each student because of the amount of work that would be required to understand what the student is like as a learner and where the student stands in relation to each of the learning objectives of the class. The new work bonus provided by the computers will provide not only the capacity to

individualize instruction, but also a new capability, through a field called "computer- adaptive testing," to clarify all sorts of useable information about the student's current knowledge, learning style, latent abilities, etc. The effect will be rather astonishing because once properly programmed, the new computer-adaptive tests will approximate having the world's finest testing psychologists available for local use for even the most economically deprived student. The programs are called computer-adaptive because they use the intelligence of the computer to hone in on an intelligent testing pattern to learn what a student knows much more quickly than a paper and pencil test which enforces a fixed sequence over a fixed time.

For example, an adaptive testing program might offer a fast 5-question scan to get a reasonable approximation of the student's ability in the area being tested, and then with another set of rapid questions close in very quickly on the exact level of the student's knowledge. The number of questions becomes a function of the level of reliability the test giver wants to achieve. Generally speaking, computer adaptive testing has three distinct advantages:

(1) It is much more accurate than standard testing.
(2) It can administer the test in far less time.
(3) The results are available immediately.

The work bonus will allow us to do things in testing that supersede any of the current practices in a school setting. For example, there will be a new kind of test called a learner profile which will build an individual profile on how a student learns as a learner. This type of information has never before been available and will help children to understand their own individual learning styles. Then over time as more is learned and more curriculum is developed, the learner profile will generate a new field called "computer-adaptive learning." The early lessons of curriculum development suggest that each area of the curriculum will continue to expand as more options are added. For example, the first reading program with audio that WICAT Systems developed required 14 megabytes of storage. Following two years of usage and field recommendations on how to improve the program, the new program was expanded to 37 megabytes. As the ESL version is adapted, that will add 80 megabytes more. It is conceivable that in a few years many different reading philosophies will have been added to expand the reading program to fit different theoretical approaches. Clearly the program could become over a billion bytes at some point. A byte is the equivalent of a single character, letter, or number. Obviously, no teacher will be able to use all of the materials available, so master "managers" will allow the faculty to set up subsets of any instructional program to fit their personal, school, district, or state biases. The "manager" is a large software program which determines what materials will be presented and what reports will be generated.

As the learner profile begins to clarify how a student learns best, and once there is a very diverse curriculum available, the new field of computer adaptive learning will arise where the learner profile will automatically begin to present materials from the curriculum that best fit the individual learning style of each user. For example, if a learner profile suggests that a student is right brain dominant and can learn better visually, then instruction will be called in that has a heavy graphics component. Or, if an analysis of a student's learner profile suggests that he needs to understand the concepts behind a math principle before he learns how to use it, then his instruction would always begin with an emphasis on "why" a concept works before teaching him "how" to use it. Conversely, for those students who just want to understand how to do the process, then their educational need will be met by emphasizing "the how" rather than the "why" of the math process.

Here we have an example of a really fundamental revolution in instruction because the educational delivery system will be able to do exponentially more work than currently is possible. There is no possible way that teachers could ever learn enough about their students and then individualize the presentations in the current delivery system. The work requirement would be exponentially more than what the teacher could offer.

There will be many other types of tests given that will have significant value as well. Probably each fall a fast scan test will be given for

learning disabilities. With the results available instantaneously, this will allow schools to pick up disabilities and start immediate remediation or sectioning as soon as school gets underway. Another test that will probably be given each fall is a test of basic skills that fit the requirements of the state that the school is located in. Increasingly, the state legislators want proof that the districts are teaching the objectives mandated by the state. Thus each fall the schools will probably give a basic skills exam that will identify how each student is doing in terms of the current objectives for his or her grade level, and it will also provide a program for remediation that ultimately will automatically link the student into appropriate instruction on the computer system. With the computer reports the district will then be able to show the status of the students and prove that the student has been given instruction and mastered the various objectives.

Other standard test packages will include national tests that help districts and states clarify their standing in comparison to other districts and states. Typically these tests are given each year, but usually a number of months in time lapse before the information becomes available.

Another type of test that will be available will be an individualized school or district level exam that can be crafted from a large test data base built to test specific objectives that the district or particular school determines are important.

Another promising new area of testing will be the computer adaptive occupational tests which will help students become aware of their unique strengths and how these strengths might apply to the prospective job market they will be joining. The tests sometimes can bring out hidden skills and link them to careers that students had never thought of. Similarly, different types of tests will help the student clarify preferences, as well as aptitudes. For example, a careful series of tests might establish that someone clearly has an unusual talent, but that he or she would prefer not to use it. The most useful type of information would not only identify potential talents, but also potential interest.

This type of information can help guide a student or adult not only into a specific career area, but also into the type of role the individual might want to have within that career. For example students should learn not only that they might be potentially good in science, but also establish whether they would prefer to teach science, be a practicing scientist as part of a large commercial laboratory, or be an entrepreneur attempting to set up a new science-based corporation.

Many of the areas of testing are not necessarily that new, but the advantages will come in having them available for everyone on a daily basis where the testing can give instantaneous feedback. Currently people with adequate capital can go to outside experts and have these

types of tests administered, but clearly there will be a distinct advantage when even the poorest child in the remotest location will have this type of information available for him or her in the years to come.

The work bonus derived from the new field of computer-adaptive testing will also generate some unusual opportunities to think freshly about serious educational problems that seem to be so fixed, that there was no use even discussing them. For example, any person recognizes that almost everything that has been taught to a student is usually forgotten over time. From a productive point of view, the process of allowing children to forget most things they have been taught at an enormous expense in capital and time has a certain sense of grand futility to it. The new test capabilities may enable us to begin to attack this problem. Tests will soon be able to establish a personal learning decay rate for each learner. Thus educators will soon be able not only to figure out how best to teach students, but also to predict how soon the students will begin to forget what they have just been taught. Once the personal learning decay rate has been established, then it will not be too large a step, using the work bonus of the computer, to calculate when a student should be refreshed in order to hold the materials. This refreshment could be totally automatic so that the computer would override any other assignment the student was working on in order to assure that the student retain earlier materials before serious learning decay takes place.

This capability to increase retention will also be used by industry. Having been trained by a corporation in some specific area, a worker will discover that the office terminal wants him to allocate 20 minutes for refreshment to maintain some skills that were taught at a 12-week course held a thousand miles away at the company training center. This training was very expensive, and having a local computer terminal automatically refresh the worker at the appropriate time will allow the student to spend very few moments to retain what has taken many weeks to learn. Furthermore, the training organization will be assured that indeed the student has taken the refresher materials and has retained the information.

As the educational institutions become more familiar with the capabilities of the computers and the extraordinary work bonus that they will afford, many new activities such as the development of the individual learning decay rate will be generated. No one can predict how the work bonus can be used, but one can predict that the testing area will begin to produce some extraordinary benefits for the children.

(7) <u>The Faculty Workload Problem</u>

The faculty workload problem is a restatement and clarification of the general delivery system work problem. The faculty member can only accomplish a fixed amount of work, and very frequently this work is inadequate to meet the needs of the students, particularly if they are a diverse group both sociologically and academically. In thinking about

the teacher's workload, very little attention has been paid to the natural work limits a teacher faces. For example, if an English teacher has 5 sections which meet 5 days a week, and in each section has 20 students, then he has to teach 100 students a week taking approximately 25 hours for his 5 classes. If he prepares for two hours a day for his 5 classes, then this adds another 10 hours, now totaling 35 hours. At a minimum he is apt to be assigned other duties such as lunchroom monitoring, study hall, playground supervision, some athletic coaching, student counseling, faculty meetings, etc. This now totals 40 hours. If he is teaching writing and is a conscientious teacher, he will probably have each class write a theme a week. If he takes 10 minutes to grade each paper, write comments, and record the results in his book, then he has taken about another 17 hours, now totaling 57 hours. Obviously, if he had the time the teacher would like to meet individually with the students and discuss the results of their writing. Unfortunately, the day is not long enough to allow this to happen very frequently, so as a result the faculty member never does have enough time, despite his best efforts, to work personally with the students to insure that they are actually improving their writing. No amount of faculty commitment or genuine desire to help the students can circumvent the mathematical limits of how much work the faculty member can do for the children. In this kind of analysis it becomes very clear that new techniques learned at writing workshops, new research from the Office of Education, new financial policies by the school district, new proclamations by the nation's leaders or the school board, and new research findings from

distinguished professors are all equally irrelevant. The teacher simply cannot do any more work. It is a work issue, and not a matter of research, morality, national will, integrity, organization, budget, etc.

This work limit can be clarified by analyzing the sequence the teacher follows when teaching writing. While grading the student papers, the teacher will have made comments on their papers and noted some of the errors that they have made. Then he usually writes a few suggestions for helping them improve their writing. The only work support he will be given in this process is a work bonus from a previous technology, the printing press. Five hundred years earlier teachers began to use books as stored work to help them in their teaching. In the example, the teacher will have assigned a writing handbook which has some organized system for clarifying the problems the students will meet. For example, the handbook will be organized either by numbers such as rule 42 or by symbols such as 'CS.' Rule 42 in one book might be CS, or comma splice, in another. When a teacher finds a student using a comma splice, which means the student has spliced two sentences together with a comma, the faculty member would then write either CS or 42 in the margin. The student then looks up the symbol in the handbook and finds a detailed discussion of the problem with many examples that help to clarify the error. This technique saves the teacher from writing a detailed explanation to the student every time he finds a standard mistake. Thus in the 10 minutes he has to write comments, the teacher can make a fairly thorough analysis of the prose and indicate, with the help of some

symbols, areas that need work and improvement. At this point, the teacher's work limits are reached, and once the paper is given back to the student, he does not have the time to do any more.

Unfortunately, the teacher runs out of work capabilities before he can assure that the student will complete the learning cycle properly. Instead of taking the paper, going back to the handbook and analyzing his errors, and then correcting them, the student is apt to count the number of mistakes he has made, look at his grade, curse his fate, and decide that the faculty member is insensitive to his literary intent or talent. The faculty member does not have time to check and see whether the student is actually making all the corrections properly and learning the lessons that have been articulated. Most observers fail to understand this work limit and are convinced that if the teacher really cared, he could help make certain that the student followed through with his corrections and learned from his mistakes. But the teacher cannot. He has already spent close to 60 hours during the week, assuming that he never pauses to relax during the day, and he just cannot do more work on a consistent basis. As a result of this work limit, what usually happens is that the student learns very little from the exchange and continues to make the same errors in future papers. The teacher recognizes that the student is not taking the time to make the corrections and assimilate the lessons, but he is powerless to do anything about it because of his time constraints.

The Computer Contribution to the Faculty Workload Problem

Where technology will help is that a work bonus will be introduced which will allow the learning cycle to be completed properly. One scenario might be that a student would take his paper to a writing center where he would be asked by a terminal to type in his name, his teacher's name, and the title of his paper. Having done this, the computer screen will then ask him to input the first symbol that the faculty member has written on his paper. Here the student might type in CS or rule #42, and the screen would then say, "John, this is the third time you have missed a comma splice. In your papers entitled "My Most Embarrassing Moment" and "An Analysis of Two Poems by Emily Dickinson," you had comma splices, and you have not yet mastered what a comma splice is. I am going to explain it to you once again, give you some drill and practice until you have mastered it, and then urge you not to make this mistake again." There would then ensue a quarter to half an hour of drill and explanation on comma splices until John can satisfy the computer program that he has mastered the concept.

Conceptually what is happening here is that the student is receiving personal instruction in precisely the areas where he needs help without the teacher being present. The work bonus has been used effectively by extending the effectiveness of the teacher. This is a simple example, and as time goes on there will be many enhancements to the concept, but

the principle is simple and very profound: The computer will allow the teacher to do exponentially more work on behalf of the student.

Another example might be drawn from an elementary class where the faculty member has never been able to allow the students to individualize too much because she is unable to work individually with them. Thus she must generally instruct the class through approximation and keep the class moving at a fixed pace for all of the students.

With the advent of the computers, many of these limitations will disappear. The computer's contribution will be that it will insure that the slower students master the materials, it will allow the middle range of students to become far more competent and thoroughly trained than before, and it will encourage the brighter students to move on at an accelerated pace. Using computer management software packages, the faculty member will be able to track all the information on the students in terms of their performance and status in relation to the class objectives. At the end of each instructional period in the computer center, a list will be given the teacher which divides the students into various groupings of approximate ability as of that day. Thus the teacher will be able to work individually with groups that are quite close together back in the classroom. The managers will also generate individual seatwork on a high speed printer that the students can take back to their room with them. Thus while some may be working with the teacher in individual groups, others might be doing individualized

seatwork with problems generated to their precise skill level at that moment. The manager will also generate individual homework for the students to take home that evening.

In order to help the teacher avoid excess grading and paper work, the individual seatwork and homework will be run through an optical scanner when the students have completed the material, and the management programs will not only grade the homework, but reset individual norms for that day's activities for each student. There will be other management programs which will help the faculty member with attendance, grading, and various administrative functions.

Cost of Implementation

In analyzing the cost for implementing computer-assisted instruction with professional systems that can have a strong educational impact, there have to be some assumptions made. These assumptions are:

(1) Each student will be put on a terminal for 1/2 an hour a day out of a total 6-hour school day. Thus 1/12 of the student time will be on an intelligent work station.

(2) There will be 4 new categories of expense for the school district:

- The cost of the hardware
- The annual lease for the software
- Annual maintenance costs to maintain the hardware
- The cost of additional personnel in the form of a paraprofessional to oversee the computer room.

(3) The cost of the hardware will be amortized over 7 years, after which it will be scrapped and new hardware will be furnished. The cost per work station on an annual basis, including the large peripherals and storage devices, the network, and the individual work stations will be $300 per year per terminal.

(4) The annual lease of the software per work station will cost $300. Schools would be well-advised to lease software because they will want the vendors to have permanent teams in position to improve and update the materials as the schools clarify what changes they want.

(5) The annual cost to maintain the hardware will be $150 per work station.

(6) The annual cost of the paraprofessional will be $450. For the purposes of planning, a paraprofessional is assumed to be paid $10 an hour for an 8-hour day even though the students will probably be only using the system for 6 hours. The extra hours can be used for preparation, and any additional days that are required for training during the year.

(7) Summarizing the annual cost per work station:

$ 300	hardware cost
300	courseware cost
150	hardware maintenance
450	additional personnel
$1,200	

Since each work station will handle 12 students during the day, the cost of the system will be approximately $100 per student per year. The $100 per student figure is a maximum. If the district is careful in its budgeting process and is willing to extend the school day for one hour in just the terminal room, then this cost could be cut further. For example, if remediation personnel or typing teachers could be assigned in

the place of a paraprofessional, there would be no additional personnel costs. Once a system is running effectively all the students will become excellent typists as part of the writing program. Many of the fifth graders at the computer research school, The Waterford School, are typing more than 40 words per minute. Thus if parent volunteers could be used, or other personnel could be reassigned because the computer is beginning to cover their functions, then $450 could be saved in personnel costs. If each terminal could handle two more students by extending the usage for half an hour before school to half an hour after school, then 14 students could be covered a day instead of 12. These two savings alone would drop the cost from $100 to approximately $53 per student per year.

(8) Giving students 1/2 an hour a day of instruction would require a budgetary increase of anywhere from 2-4 percent for the district. Schools will be hard pressed to defend how any other budgetary increase of 2-4 percent would have anywhere near the impact of implementing computers in the district.

Possible Productivity Gains

The $53-$100 a year scenario, or 2-4 percent budgetary increase, can actually end up as a savings if a school district wants to initiate productivity gains as they implement the hardware. These productivity gains are drawn from the following assumptions:

(1) The average national class size is approximately 21 students per section.

(2) If the higher figure is used, then it would cost 21 x $100, or $2100 per section, to add computer-assisted instruction for each class.

(3) The national per-pupil cost figure is $2724 per student per year.

(4) If the section size were increased by one student when computers were added, the district would save $2724 per section. By adding one more student the cost of computer instruction for the class would go from $2100 per section to $2200. The summary of the cost benefits for the section is:

$ 2,724	saved by adding one student
- 2,200	cost for adding computer-assisted instruction for 1/2 hour a day
$ 524	savings per district that adds one student per section

Obviously there would be many critics who would say that we need smaller section sizes, not larger, because the students need more individual instruction. But the addition of the computerized instruction will give the students more individual instruction even if the section size rises.

Furthermore, as the systems become more effective and the schools learn to use them, the addition of another student per section could allow the students to extend their time to an hour a day on the computer and still be saving the district money. Thus for those districts that can control their personnel and financial policies, the addition of computer-assisted

instruction can represent a financial savings while significantly increasing the effectiveness of instruction. Districts will begin to extend their usage of the systems from 1/2 an hour a day, or 1/12 of the students time, to 1 hour a day, or 1/6 of the student time. This time expansion will gradually evolve for a number of reasons:

(1) The teachers and administrators will realize how useful and helpful the technology is in improving the students instruction.

(2) Because of declining hardware cost and increasing efficiency in the use of the personnel and the computer system, an hour of instruction on the computer will cost no more than the 1/2 hour previously did, i.e., $50 to $100 a student per year, or 2-4 percent of a district's budget. And once again, if a single student is added to each section, the hour of instruction will be paid for and the district will actually save money.

(3) As the educational productivity problem begins to be understood more clearly, and the educational, state, and national leadership realizes that salaries must stagnate unless productivity gains can be forced upon the delivery system, then a pressure will build up to add computers to schools in order to increase productivity and raise faculty salaries.

The Technologies of the New Educational Delivery System

There will be a number of competing technologies that offer great promise in the new educational delivery systems. Some of them are:

(1) Inexpensive home computers

(2) Standalone personal computers with more power and storage.

(3) Networked personal computers

(4) Professional educational computer systems

(5) Videodiscs and CDROMs.

An educational leadership will become quite confused by the various technologies and will not find it easy to make the right choices. There are a number of issues which are helping to confuse the leaders:

(1) The most accessible computers, the personal computers, are not designed for optimal instructional effectiveness. They lack the ability to handle large instructional programs efficiently.

(2) The strongest marketing organizations are those associated with the personal computer marketing. Thus the prime exposure to computer technology that the educational leadership will experience will come from the salesman from the personal computer vendors. Conversely, those firms that have built the best hardware for educational usage do not yet have as strong a presence in the marketplace and have a couple of disadvantages:

- Professional educational delivery systems come in clusters from 5 to 30 terminals, so the districts must purchase the systems as a whole. Thus the district cannot purchase the equipment one terminal at a time.
- The vendors of the professional systems are viewed as sellers of specialty systems instead of systems which will have many companies building software for them. In the education market, as the paper clarifies, open systems and serious education are <u>not</u> synonymous because of the integration problem. All good instructional systems will be closed, including the PC systems. Thus the proper decision

will hinge on how complete the courseware will be for any given closed system. Ultimately the best closed systems will have more courseware available than the students can use, as they will not be closed in the sense of being restrictive.

Thus a school district has a choice of making a decision to purchase hardware that will have less instructional impact on the students that can be implemented easily or to purchase professional systems that require more initial capital but which can be far more effective instructionally. The personal computer marketing organizations initially will have more salesmen than the newer professional system companies, so further complicating the decision sequence will be the dilemma the districts face in having stronger marketing from the large personal computer corporations. In other words, districts are going to have a confusing time trying to make an objective decision as to what will be best for the children.

(3) There is a serious misunderstanding as to how much quality educational courseware is available. A good course such as Algebra I requires a million dollar investment and takes a number of years to build. Then after it has been in the market for a few years, a great deal more money has to be spent making changes to improve the product. In order to develop all the appropriate courses from pre-school through the early college years that will have a strong educational impact on the students, $100 million will have to be spent on each specific delivery system. Most developers of educational courseware have been spending $10,000 to $75,000 for producing educational packages. These little tiny packages tend to have a nice graphic with some sort of attractive interaction.

But they do not produce very useful units for a school. Trying to splice a hodge-podge of these units together, all of which have different educational philosophies, does not constitute a curriculum that has any significance. Yet if educational leaders are asked if there is a great deal of curriculum available, they almost universally will say that they have a broad choice and that various organizations are giving them recommendations on which packages to purchase. In reality, good curricula are really just becoming available with some companies having spent as much as $40-$50 million on the development of the software and courseware required for the first wave.

(4) Districts do not realize there will really be five areas of software and courseware development.

- There are the courses themselves which require significant developmental efforts. For example, the current state of the art program size for teaching children to read with audio in a mixed class of English-speaking and non English-speaking students is approximately 125 megabytes. Within a few years as improvements are added the program size could swell to a billion characters for the one program.
- Almost as important as the courseware development, but unknown to many administrators, is the requirement for very powerful computer manager programs that will link the courseware together and allow the teacher to present the appropriate materials for the students at the right time. These managers will also generate reports and an analysis of student trends that will be useful to the faculty. Without a good manager program, the student rarely uses the computer

time appropriately and the faculty member rarely understands what the student has or has not learned.

- The whole new field of computer adaptive testing is requiring a significant programming effort in its own right. Here again the testing programs will have to be integrated with the managers and the courseware. The school leadership has little understanding of how profound the impact of testing will be, and almost no understanding of how complicated it will be to link real time testing results with the managers that will control the curriculum presentation to the students.
- Most school districts have already worked with computers with administrative packages, but there will be a new software effort required to expand the scope and depth of administrative programs to fit the new potential that the computers will deliver. There will also be a new pressure from state legislators to produce administrative proof that their mandated instructional objectives are being met by the schools. This means that there will be another integration effort required so that the administrative packages will have to interact with the tests, the managers, and the courseware.
- The fifth significant software development area is the construction of an authoring system which will allow the districts to develop their own instructional materials for the computers without using programmers. As professional development corporations begin to put tens of millions of dollars of development funds into the production of courseware, they are spending millions of dollars in software tools to help facilitate the development process and save them money.

These authoring systems save time, money, and frustration by allowing the instructional experts to work directly on the computers without having to work through expensive programmers. Authoring systems are to the instructional process what word processors are to the office process. They also allow the materials to be changed without incurring a great deal of additional expense, just as a good word processor will allow executives to iterate on letters and reports. The practical implications of authoring systems are that they will allow materials to be developed at approximately 1/3 the cost in half the time. There is a vast difference between professional authoring systems and those that are available on personal computers. Here again the districts will be somewhat confused by the marketing organizations, all of whom will tout an authoring system.

(5) Although the districts all like the idea of an open architecture, the complexity of developing the courseware and integrating it with managers, tests and administrative packages will force the districts to purchase total solutions from single vendors if they desire to achieve the maximum instructional impact on their students. The day of splicing together little packages will gradually draw to an end because the packages have only minimal instructional effectiveness and they will not collectively form a sound coherent instructional, management, testing, and administrative package. Understanding this is somewhat counter-intuitive to the approach being followed by most administrators at the present time. They feel that somehow there is more protection in having lots of

small packages available than an integrated whole; whereas, this approach actually guarantees only minimal instructional effectiveness.

(6) Vendors have confused the school systems by selling them hardware that would be useable for computer literacy and learning computer programming, but not very helpful for instruction. The vendors have done this because they wanted to increase their overall percentage of sales for personal computers. Administrators being sold the materials have been encouraged to believe that the primary use of the computers will be to increase computer literacy for the students and to teach them some programming. While these contributions are important, they do not touch on the potential of the computer to improve all instruction. Personal computer sales have been generated in a cynical fashion by large companies attempting to increase market share, and frequently they have left districts with a great deal of equipment that has little instructional efficacy. The results of these sales policies have damaged the school computer movement by providing critics with the ammunition to argue that computers are just new technological toys that are not turning out to be effective.

A second confusing sales cycle is under way where administrators are being told that the reason the first round of personal computers did not work is because they were not networked together. This allows a vendor to sell a large disk storage device called a file server to connect all the personal computers together. Thus there will be another rush of purchases to link personal computers to file servers in a network without

ever taking the fundamental question on of how effective these systems can be instructionally.

Summary: The educational leadership will have to be very careful to protect themselves as they make decisions about educational hardware. They should do this by continually working at understanding the need to make the decision primarily an educational one. Above all else, they must guard against being sold disparate pieces of unintegrated and ineffective educational software designed to run on personal computers that were never designed for educational usage. They will have to work hard to study the materials available and work towards hardware and software acquisition that will allow them to utilize the full potential of what the new educational delivery system can offer for their children. If the educational leadership does not take the trouble to understand the core issues, then they will be manipulated by the vendors who can make more money by selling their standard products than by trying to sell products that fit the real needs of education.

Overview of the Hardware Revolution

The Home. For a period parents were fooled by the manufacturers of inexpensive personal computers, all of whom have made the educational potential of their systems a major marketing thrust. Unfortunately, the early personal computers had neither the power or storage capabilities to do serious instruction, nor did the computer companies spend any money on the development

of the educational materials. They tended to introduce cartridges or small diskettes which had programs of a few thousand bytes that cost a few thousand dollars to develop. As is traditional, millions and millions of dollars were spent on advertising and marketing, but very little on the educational materials. The parents responded appropriately, and after being fooled for a time, they have not purchased personal computers in anywhere near the numbers that had been anticipated.

Soon there will be a new round of more serious courseware emerging that first will be marketed to the schools to achieve academic respectability, and then these materials will be offered to the home. These materials will have some excellent instructional effectiveness. They will not be as powerful as the instructional programs on the professional systems in the schools, but when supported by the parents in the proper atmosphere, their children will be able to do some useful learning. The more advanced schools may even provide some software for the students to take home.

There is the technical possibility that students will someday be able to call into professional systems at the school while working on their personal computers at home. The professional systems will offer individual tutorial guides that will help them solve homework problems when they run into unexpected difficulties that neither they nor their friends can solve. Linking into the professional systems will also be a help in providing improvement management information to the schools and parents who will better be able to follow the results of their children's efforts. Students working at home may someday be able to connect to a friend's house through the school's computers. This may allow them to work on homework together.

In another generation there will be two new media introduced which incorporate laser devices that will greatly enhance the effectiveness of home instruction. The first of these is the videodisc. The videodisc is the ultimate instructional device because it combines, when linked with a personal computer, the power of the three most useful educational technologies. Thus the videodisc will have the motivational power of movies with excellent audio, the power of the book, with a capacity to store tens of thousands of pages of text, color photographs, or graphics, and the power of the computer to offer individual instruction through various artificial intelligence techniques. The problem of the videodisc is that it also combines the expense of developing courseware materials for these 3 technologies. Gradually, however, as the home entertainment market allows the distribution of more laser players there will be enough of a potential market to generate the required educational investment in the videodisc.

The second device, the Compact Disk or CD as it is known, will allow extraordinary amounts of program size to be stored with a personal computer in the home. Here again the consumer market is helping to drive the CD player as more and more consumers are beginning to purchase the CD disks for music. This will drive the price of the drives way down, and at some point in the future instead of storing music on some disks, very large computer programs will be put on the disks which will be technically called CDROMs. The phrase ROM means Read Only Memory, which suggests that the disks will be permanently pressed with a program that can only be read and not changed. The technological capability to use the CDROMs will be available long before they

will have serious educational usage. The educational vendors will be reluctant to put their courseware on the CDROMs because the really large programs that can be stored on the CDROMs are not yet bug free. Also, the instructional programs will be in a rapid state of change and flux over the next decade as changes are constantly made to produce instructionally effective programs. At some point in the future, however, once the rate of change slows down, the new more powerful personal computers will be able to store very large and powerful instructional programs on the CDROMs that will offer a serious instructional alternative to the parents with children at home.

The Schools. Phase I of the school market has been the introduction of the personal computers which have had marginal instructional effectiveness but which have been of great help in teaching computer literacy and computer programming. They have been easy for the schools to acquire incrementally. Phase II will get underway in 1986 as two types of systems will be vying for the marketplace. The personal computers will begin to be networked by some of the large vendors and some more serious courseware will be introduced which the networks will be able to handle. Competing with these networked personal computers will be professional systems introduced by vendors who will argue that these machines will be far more effective instructionally because they have been built to meet a specific market need. From the standpoint of the school this means that the professional systems will have unlimited audio, graphics and animation, and the capability to implement programs of enormous size without any networking constraints. The professional systems will also begin to integrate the courses, the managers, the testing, and the

administrative packages. They will also offer outstanding authoring systems to the school districts.

In the end, there will be little price difference between the professional systems and the personal computers. For the foreseeable future as some of the large corporations try to clear out their inventories of older personal computer technology, the personal computers may appear to have a financial advantage, but as soon as the clearance is over, the personal computers and the newer professional systems will be very closely priced.

Phase 3 will start in a few years as the videodisc materials begin to come on stream and will be integrated into the school personal computer and professional system networks. Their entry will be at a modest pace because they will add significant instructional costs on a per work station basis. Schools will have to be very sensitive to the per work station cost because they will be purchasing many more terminals than they had anticipated once the effectiveness of the instruction becomes apparent. The schools will start at about 1 terminal for each 12 students and evolve into 1 terminal for every 6 students. Since the videodisc could triple or quadruple the cost of a work station, it will probably enter the school market rather slowly even though it may be educationally more effective.

The CDROMs school usage will take many years for different reasons. They will be of great use with the more advanced PCs as time goes on, but they will still require that the personal computer be networked in order to complete the management, testing, and administrative integration and reporting. But the

educational courseware will be changing too rapidly to use very many CDROM's for the foreseeable future. Once the hardware, software, and courseware packages are integrated and begin to mature, then the CDROM's will begin to appear with some frequency. There will be no price advantage in using CDROM's, but they will allow the networked personal computers to become more effective because they will get rid of the program size limits generated by normal networking PCs. Even after the PC vendors have the option to develop much more effective courseware to take advantage of the storage capability of the CDROM's, there will be a delay of many years before they do so because it will take them years to develop and debug large programs, and they will have to recover the cost of developing and selling the first set of programs before they start the new cycle. Furthermore, corporations are going to have severe pricing problems in trying to price large programs on small inexpensive CDROMs. These factors should delay extensive use of the CDROM's for quite a few years.

Customers may prefer to stay with professional systems that will cost as little or even less than the networked systems with CDROMs because of the ability to constantly update their courseware and write their own modifications using the authoring system. In this way districts could shape their tests and courses to fit local needs. This will not be possible on CDROM's because they are not built to be changed, much as an L.P. record cannot be changed.